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Global zero emission scenario: role of innovative technologies

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Abstract

This study investigated a zero emission scenario with following two originalities compared to various existing studies. One is that we based on A1T society of SRES (Special Report on Emissions Scenario) of IPCC (Intergovernmental Panel on Climate Change) compared to existing studies on those of B1 or B2. The second one is that various innovative and radical technologies were considered and incorporated, such as biomass energy with CCS (BECCS), and advanced nuclear technologies including hydrogen or synfuel production. We applied a global modeling, whose energies, materials, and biomass and foods supply costs were minimized by linear programing with time horizon up to 2150. We found following features of energy supply structure in A1T scenario. Since the electric demand in A1T scenario in 2100 is two times larger than the others, 1) renewable energy which solely produce electricity, nuclear, and fossil energy with CCS (FECCS) especially coal are main sources of electricity, 2) renewable which can supply heat, namely BECCS and geothermal, satisfies the sector, and 3) hydrogen from coal is introduced in transport sector. It can be concluded that the zero emission energy systems with global economic growth will be possible, by development and deployment of ambitious advanced energy technologies.

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zero emission; BECCS; SRES; A1T scenario

1. Introduction

The objective of the United Nations Framework Convention on Climate Change (UNFCCC) is "stabilization of greenhouse gas (GHG) concentrations in the atmosphere at a level that would prevent

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dangerous anthropogenic interference with the climate system" [1]. There is, however, no consensus on a precise level of CO2 in the atmosphere that would prevent such interference. Reaching the target of climate stabilization at no more than 2°C above pre-industrial levels by the end of this century is interpretation of the Article 2 by European Union (EU), which corresponds to be some 450 ppm CO2 equivalent. Exiting studies [2] (reviewed in IPCC-AR4 [3]) show zero or negative emissions, however, such scenarios are unclear how they can be built. In the present work, we concentrate on creating zero emission scenarios on energy and material cycle and stabilized CO2 concentration to minimize the risk of the climate change and its related impacts.

2. Outline of our analysis

Our analysis finds a possibility to identify possible zero emission scenario with A1T society that allows sustainable development and economic growth in particularly developing countries though many existing studies were based on less economic development paths such as B1 or B2. It is considered to be more realistic because majority of the developing countries including middle east actually heading to the high growth rate policy. The A1T scenario, if it will be implemented, allows GDP of the world total at the end of the century larger than 500 trillion $ equivalent, while total population turns to decrease to 7 billion, resulting more than 70000 $ per capita GDP.

Our analysis involves various innovative technologies with technological confidence, based on the currently investigated and developed with future market possibilities combined with socio-economic evaluation. Some of the advanced technology innovations are considered and incorporated, such as advanced solar energy, improved biomass utilization for recycling combined with CCS, and advanced nuclear technologies, by which use of energy for fuel production to substitute fossil energy. Technological data including SRREN (Special Report on Renewable Energy Sources and Climate Change Mitigation) [7] that allows maximum possibility of renewables introduction is considered, combined with enhanced biomass utilization and carbon absorption with it. Biomass flow was modelled for Carbon accounting to incorporate bio-CCS and enhanced absorption by captured CO2.

With the optimized energy mix, the model is applied for the world divided into 10 region groups, and the total supply costs of energy, biomass and material were minimized by linear programing from 2010 to 2150, with the discount rate of 2%. In order to simulate zero emission scenario, an emission constraint resembles to WRE 350 [6] from 2010 to 2150 is given. It should be noted that the zero-emission is an extremely strict limit, and also is slightly different from the current 350 ppm scenario.

3. Result - zero emission scenario towards 2100

One of the examples of the zero emission scenario is shown in the Fig. 1, that describes the profile of the CO2 production from each energy sectors and the total release to the atmosphere. It was found that net zero emission will be possible in the latter half of this century. As seen in the figure, carbon sequestration followed by the biomass based energy has a significant contribution to reduce the net emission, particularly to absorb the unavoidable emission from fossil use from industry and transportation.

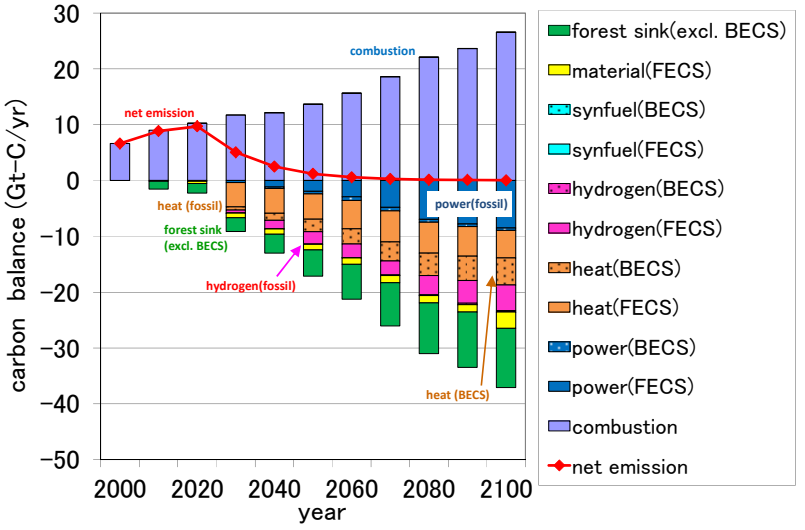

Fig. 1. Carbon balance under the zero emission scenario

4. Discussions

Figure 2 summarise energy supply structure of the zero emission scenario under SRES-A1T scenario. Here we categorized renewable energies into two; one is solely produce electricity (denoted as “ele-ren” hereafter), the other one can produce both heat and electricity (“heat-ren” hereafter). Since “ele-ren” and nuclear can solely provide electricity, those go to huge Electricity demand in SRES-A1. Fossil energy also goes to electricity with CCS, but fossil energy also needs to meet transport demand by hydrogen from coal as well as conventional gasoline and light oil. Hence, “heat-ren” such as BECCS as well as geothermal satisfies heat demand with the help of FECCS.

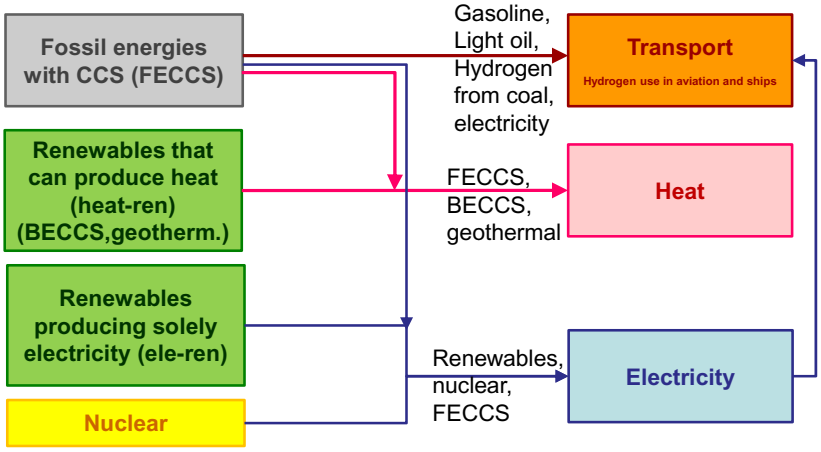

Fig. 2. Energy supply structure of zero emission scenario under SRES-A1T

Our result by a simplified climate model in this zero emissions scenario suggests that atmospheric CO2 equivalent concentration may fall to 400 ppmv in the end of this century, and that the average temperature increase will be in the range of some 2 degree, and at the same time such enhanced GDP will

allow better preparation for the various impacts of the climate change effect and reduce the vulnerability to the disaster significantly.

This scenario strongly depends on the improvements of the technology in all the energy fields of renewable, nuclear and CCS. Radical absorption and sequestration technology (BECCS) is also needed, especially in heat supply in industry sector. Drastically increased dependence on biomass results significant impact of the method of carbon accounting on the cost of the biomass related technologies that leads different energy portfolio favoured by it.

5. Conclusion

This study investigates a zero emission scenario with A1T society of IPCC-SRES that allows sustainable development and economic growth in particularly developing countries. In order to draw the zero emission scenario, we adopted a global modelling, whose energy, biomass and material supply costs were minimized by linear programing from 2010 to 2150. In order to simulate zero emission scenario, emission constraints resembling to WRE 350 from 2010 to 2150 are given as an emission constraint. Some of the advanced technology innovations are considered and incorporated, such as advanced solar energy. The model simulation suggests that BECCS for heat, other renewables such as solar, wind, and ocean, and FECCS and nuclear for power, hydrogen production for coal with CCS, and synfuel for gas with CCS are required to meet the zero emission scenario.

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References

[1] UNFCCC (1992). United Nations Framework Convention on Climate Change. http://www.unfccc.int/resources.

[2] Azar, C., Lindgren, K., Larson, E. and Möllersten, K. (2006). “Carbon capture and storage from fossil fuels and biomass - Costs and potential role in stabilizing the atmosphere.“ Climatic Change, 74(1–3): 47–79.

[3] Metz, B., Davidson, O., Bosch, P. R., Dave, R. and Meyer, L. A. eds., Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assess ment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK and New York, NY, USA: Cambridge University Press

[6] Wigley, T.M.L., R. Richels & J. A. Edmonds (1996), Economic and Environmental Choices in the Stabilization of Atmospheric CO2 Concentrations, Nature. 379(6562).

[7] O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. Eickemeier, G. Hansen, S. Schlömer, C. von Stechow (eds). IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA

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